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EFFECTS OF SEAWATER AND DEIONIZED WATER AT 0 TO 80°C ON THE FLEXURAL PROPERTIES OF A GLASS/EPOXY COMPOSITE

(Center Director's Discretionary Fund Final Report)

B. G. Penn, J. G. Daniels, F. E. Ledbetter, III, M. L. Semmel, B. G. Goldberg, W. T. White, and J. M. Clemons

Space Science Laboratory
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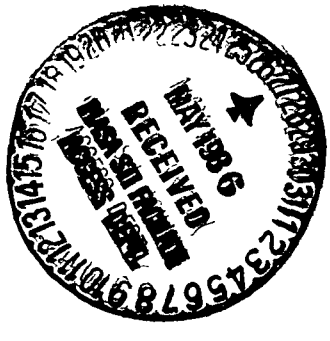

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16. ABSTRACT

@ ABS The effect on the flexural properties of a glass/epoxy composite of immersion in deionized water or seawater at 0°, 25°, and 80°C for 451 hr was examined. The percent weight gain at 0° and 25°C was low (0.06 to 0.17 percent) and there was no significant change in the flexural properties for these environmental conditions.

← At 80°C there was a decrease in the flexural strength of 17 and 20 percent in seawater and deionized water, respectively. This is a comparison to control samples exposed to 80°C heat alone. These decreases were found to be nearly reversible once the samples were dried. Optical microscopy did not reveal cracking of the matrix. The flexural modulus was essentially unaffected by exposure to deionized water and seawater at 80°C.

@ DBA Author

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Authors: B. G. Penn, J. G. Daniels,** F. E. Ledbetter, III,** M. L. Semmel,** B. G. Goldberg,** W. T. White,** and J. M. Clemons**

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EFFECTS OF SEAWATER AND DEIONIZED WATER AT 0 TO 80°C ON THE FLEXURAL PROPERTIES OF A GLASS/EPOXY COMPOSITE

INTRODUCTION

Composite materials are widely used in applications requiring high strength, high stiffness, and low weight such as usage in automobiles and aircrafts. In order to take full advantage of these excellent properties, the effects of service environments such as heat, temperature, and moisture on the mechanical properties of composite materials need to be determined.

The effects of temperature and moisture on the mechanical properties of epoxy resins reinforced with graphite [1-7] or glass fibers [8-11] have been studied. Degradation of properties is believed to occur by moisture-induced plasticization or moisture-induced cracking of the epoxy matrix [7-8]. Moreover, degradation of glass fiber reinforced composites may occur by leaching of constituents from the reinforcement fibers [8].

The purpose of this paper is to present the results of a study concerned with determining the effects of seawater versus deionized water on the properties of a glass/epoxy composite.

EXPERIMENTAL PROCEDURE

Materials

Stratoglas glass/epoxy rod (1/4-in. diameter) was obtained from Air Logistic Corporation, Pasadena, California. This composite, which consists of S-glass and a proprietary epoxy resin, is prepared by a continuous molding process. The curing agent is an amine.

The dry seawater salt mixture was purchased from Lake Products Co., St. Louis, Missouri. The composition of this mixture is shown in Table 1. The seawater solution was prepared by dissolving 41.95 g of the salt mixture in 1000 mL of water as specified by the supplier.

Environmental Testing

Five-inch lengths of glass/epoxy rods were immersed in seawater at 0°C, 25°C (room temperature), and 80°C for 451 hr. Control samples were prepared by subjecting specimens to 80°C in a dry environment and to storage in a dessicator at room temperature. After environmental exposure, the samples were subjected to microscopic examination, percent weight gain determination, and flexural strength and modulus measurements.

Percent Weight Gain Determination

The percent weight gain values presented in Table 2 are the average of two 5-in. length samples of glass/epoxy rod. The weight measurements were made using a Mettler AE 160 analytical balance which has a readability of 0.1 mg.

Microscopic Examination

Environmental exposed and control samples were examined for cracks using a Nikon SMZ-100 stereomicroscope at a magnification of 35X.

Fiber Content

The weight percent of fibers was 70 to 77 percent according to the manufacturer.

Flexural Testing

Testing was carried out in accordance with ASTM-D790 using the four-point bend geometry. The length of the glass/epoxy rod samples was 5 in. The support span and load span were 2 and 0.67 in., respectively. The tests were carried out using an Instron testing machine at a rate of 0.1 in./min. Five samples were used in determining environmental effects on the controls and current specimens (samples tested immediately after removal from the environment). Four samples were used in determining the flexural properties of residual specimens (samples that were dried to constant weight after environmental exposure and then tested).

RESULTS AND DISCUSSION

Percent Weight Gains in Seawater and Deionized Water

The percent weight gains of samples immersed in seawater or deionized water for 451 hr at 0°, 25°, and 80°C are summarized in Table 2. The range of values obtained at 0° and 25°C are low (0.06 to 0.17 percent) and there is no significant difference in the effect of seawater versus deionized water for these environmental conditions.

At 80°C there was a significant increase in the percent weight gains of samples exposed to seawater and deionized water compared to values obtained at 0° and 25°C. The value obtained after immersion in seawater (1.2 percent) is not considered to be significantly different than the percent weight gain measured after immersion in deionized water (1.3 percent).

A white coating was observed on the samples immersed in seawater at 80°C which could affect the long-term percent weight gain of the glass/epoxy composite. This is based on work by Mazor et al. [12] who immersed graphite/epoxy composites in seawater and deionized water for 11 years. These investigators found that samples immersed in deionized water had the highest percent weight gain. The explanation given for this result was that a thin coating formed on the surface of samples

immersed in seawater and acted as a barrier to absorption. In the present work the samples were only partially covered; however, during long-term environmental exposure, a more complete coating may form thereby decreasing the weight gains for samples exposed to seawater.

Environmental Effects on the Flexural Properties

The effects of immersion in seawater and deionized water for 451 hr at 0°, 25°, and 80°C on the flexural moduli and strengths are summarized in Table 3. The flexural moduli values for deionized water and seawater at 0° and 25°C ranged from 5.99 to 6.21 Msi which is not significantly different than the value obtained for the control (5.99 Msi). Moreover, the range of values (128 to 133 Ksi) obtained for the flexural strengths did not vary significantly from the value of 132 Ksi measured for the control sample. These results are not surprising because of the low percent weight gain values of 0.06 to 0.17 percent found under these conditions. In addition, visual and optical microscopic examination did not reveal cracks.

At 80°C there was a significant decrease in flexural strengths of samples after immersion in seawater and deionized water; however, the flexural modulus did not change significantly. For example, compared to samples exposed to 80°C heat alone, there was a decrease of 17 percent for samples immersed in seawater versus a value of 20 percent for the samples immersed in deionized water. These decreases were nearly reversed once the samples were dried. For example, samples immersed in seawater or deionized and dried had only a 5 percent decrease in flexural strength compared to the control which was heated to 80°C in an inert environment. This is not considered to be significant since the standard deviations for the test samples were 1.5 to 3.4 percent. For this same reason, the difference in the flexural strengths of seawater versus deionized water immersed samples at 80°C is not considered to be significant.

The decreases in the flexural strengths of samples immersed in seawater or deionized water for 451 hr at 80°C are most likely due to plasticization of the matrix material as indicated by the 1.2 and 1.3 percent weight gains obtained under these conditions (Table 2). Optical microscopy did not show moisture-induced cracking under these environmental conditions. In addition, there was not a significant amount of material leached out of the immersed samples based on their dry weight after environmental exposure.

CONCLUSION

In this study, glass/epoxy samples were immersed in seawater and deionized water at 0°, 25°, and 80°C for 451 hr. There was no significant difference in the effect on the flexural properties of immersion in seawater versus deionized water for the composite system used in this study.

At 0° and 25°C there was no significant difference in the flexural properties of the immersed samples (deionized water and seawater) compared to the control samples which were stored at 25°C in a dry environment. This is most likely due to the small amount of water absorbed by the test specimens under these conditions. For example, the percent weight gains were 0.06 to 0.17 percent.

There was a decrease of 17 percent in the flexural strength of samples immersed in seawater at 80°C and 20 percent for those immersed in deionized water; however, the change in the flexural modulus was not significant based on a comparison of immersed samples and control samples exposed to 80°C heat in a dry environment. The significant decreases in the tensile strengths of the immersed samples are most likely due to moisture-induced plasticization based on percent weight gains of 1.2 and 1.3 percent for the seawater and deionized exposed samples, respectively.

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TABLE 1. COMPOSITION OF SEAWATER SALT MIXTURE ACCORDING TO MANUFACTURER

Component	Percent Composition
NaCl	59.490
$MgCl_2$	26.460
Na_2SO_4	9.750
$CaCl_2$	2.765
KCl	1.645
$NaHCO_2$	0.447
KBr	0.238
H_3BO_3	0.071
$SrCl_2$	0.095
NaF	0.007

TABLE 2. PERCENT WEIGHT GAIN FOR GLASS/EPOXY SAMPLES AFTER IMMERSION IN SEAWATER AND DEIONIZED WATER FOR 451 HOURS

Temperature (°C)	Percent Weight Gain	
	Deionized Water	Seawater
0	0.09	0.06
25	0.13	0.17
80	1.30	1.20

TABLE 3. EFFECTS OF IMMERSION IN DEIONIZED WATER AND SEAWATER AT VARIOUS TEMPERATURES FOR 451 HOURS ON THE FLEXURAL MODULUS AND STRENGTH (Values for the controls at 25°C were 5.99 Msi and 132 Ksi and at 80°C they were 6.02 Msi and 135 Ksi, respectively.)

Temperature (°C)	Flexural Modulus (Msi)		Flexural Strength (Ksi)	
	Deionized Water	Seawater	Deionized Water	Seawater
0	6.21	6.21	134	133
25	6.13	5.99	128	133
80				
a. Current	5.99	6.28	108	112
b. Residual	6.02	5.79	129	128

APPROVAL

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This work, in its entirety, has been determined to be unclassified.

A. J. DESSLER
Director, Space Science Laboratory

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